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MESOCLIMATIC TEMPERATURE DIFFERENCES IN THE FORT GREELY, ALASKA, AREA

QUARTERMASTER RESEARCH & ENGINEERING CENTER
EARTH SCIENCES DIVISION

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Quartermaster Research & Engineering Center
Natick, Massachusetts

EARTH SCIENCES DIVISION

Technical Report
ES-3

MESOCLIMATIC TEMPERATURE DIFFERENCES IN THE FORT GREELY, ALASKA, AREA

Arthur V. Dodd
Meteorologist

Regional Environments Research Branch

Project Reference:
7X83-01-008

April 1962

FOREWORD

The extensive and continuing use of the Fort Greely area by the Arctic Test Board and other Army agencies necessitates a more detailed knowledge of the local variations in the environment of the area. Using data that were collected by the Air Weather Service and the Army Signal Corps, a meteorologist of the Quartermaster Corps has analyzed these variations as to their extent, geographical distribution, and causes. The results of this study were first presented in a paper before the Alaskan Science Conference at College, Alaska, in August 1961. The present report contains the same material as that paper, supplemented by photographs of stations where observations were made. Maps are included showing the pattern of temperature differences in both winter and summer.

This report illustrates the great differences in temperature that can occur within relatively short distances as a result of Fort Greely's situation near mountain passes in an area of frequent air mass changes in winter. It is essential that these differences be considered in the planning of winter tests in the area, and the maps and conclusions presented here are designed to assist such planning. This report is also an important addition to the meager body of scientific literature on mesoclimates.

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ABSTRACT

Temperature observations by thermograph at several points within 20 miles of the Federal Aviation Agency Weather Station at Fort Greely, Big Delta, Alaska, are discussed. The thermograph observations were taken at a number of sites over a 4-year period by Air Force and Signal Corps meteorological groups.

Patterns of temperature differences during winter and summer between the thermograph sites and the Federal Aviation Agency station are presented. Large variations in temperature are caused by the nearby mountains and the rapid development and dissipation of the Arctic inversion with changes in radiation balance and mixing by wind. Differences in temperature in the Fort Greely area of as much as 40F° between sites within 1 mile of each other, but in different terrain situations, are not unusual during clear winter weather. The pattern of differences varies from cold spell to cold spell. Several sites in the area did not experience temperatures below -35°F during 3 years of observations, while other sites frequently experienced temperatures below -50°F.

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MESOCLIMATIC TEMPERATURE DIFFERENCES IN THE FORT GREELY, ALASKA, AREA

1. Introduction

In climatic studies three scales of measurement are often delimited. For large-scale regional analyses the macroclimatic scale, using "standard" observations at sites intended to be representative of large areas, is appropriate. Such observations, ideally, are designed to eliminate differences which result from local terrain, vegetation, or cultural features, although at many sites these differences are not eliminated. The most detailed scale is the microclimatic scale which is appropriate when very accurate information on a small scale is needed. For this, special instrumentation is generally required. Mesoclimatic measurements are between these extremes of scale and share characteristics of both. They very often are standard in that they are taken in the same manner as macroclimatic observations, but they are intended to show the temperature or other climatic regimes of small areas which may be significantly different from the regime at a nearby so-called "standard" site*.

At Fort Greely the macroclimatic record consists of meteorological observations taken by the Federal Aviation Agency (formerly the Civil Aeronautics Administration) since 1942**. Because this single observation point does not adequately represent the climate of the Fort Greely area, several government agencies have conducted mesoclimatic or microclimatic observational programs in the area. As early as 1952 mesoscale measurements were made by a detachment of the Air Weather Service, USAF, to confirm the observations of test personnel that at times it was much colder in testing areas than reported at the FAA Weather station.

In March 1955, the observational program was expanded from 6 to 19 stations to meet a requirement of the Military Geology Branch of the United States Geological Survey(2). Thermographs were installed at all stations and checked periodically.

In the meantime the Quartermaster Corps, charged with responsibility for applied environmental research, and recognizing the significance of local climatic differences in military test areas, planned observational

*The terminology used here is in general agreement with definitions in the Glossary of Meteorology published by the American Meteorological Society in 1959 (1).

**The weather station is now designated "Big Delta FAA".

programs in arctic, desert, and tropical locations to assess the nature and extent of these differences. The Signal Corps was requested to make these mesoclimatic and microclimatic observations. At Fort Greely, Quartermaster plans were merged with the existing observational program of the Air Weather Service detachment, and a Signal Corps meteorological team was given responsibility for conducting much of the expanded program. One phase of this program included detailed microclimatic observations in a spruce forest and at a nearby open site. Data from this phase of the program, including measurements of temperature profiles from beneath the ground to a height of 4 meters, have been analyzed and published (3).

The second phase of the expanded program was an extension of the thermograph network to 24 sites; observations at these sites were taken until August 1957. These mesoclimatic observations are considered in this report. They have already been analyzed by Major James Evans, who was Commanding Officer of the Air Weather Service detachment (4,5) and one of his maps is included here. All records were tabulated and verified by a Weather Bureau group at the National Weather Records Center.*

2. Mesoclimatic observational program and procedures

The locations of the mesoclimatic stations are shown in Figure 1. All stations had thermographs in instrument shelters with calibrated thermometers to check the thermographs.** Supplementary observations of soil temperature, maximum and minimum temperature just above the surface, and summer precipitation were taken at some stations, but none of this information is analyzed here.

It was not possible to maintain all stations for the 3 years of observations. In general, records are more complete for the warm months and for the more accessible sites. During periods of extreme cold, thermograph clocks often froze and valuable records were lost. Other natural hazards, such as damage to instruments by bear or buffalo, also affected the quality of the record. The considerable amount of valuable data accumulated is a tribute to the many people who participated in this difficult observational program.

Originally it was planned that the data would be placed on punched cards and the analysis would be carried out by machine methods. However, this was not practicable because of the large amount of missing data.

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*Copies of the data were furnished the Quartermaster Research & Engineering Center and Detachment 6, 7th Weather Group, Fort Greely, Alaska.

**See Appendix for photographs of selected thermograph sites.

FORT GREELY AREA - ALASKA

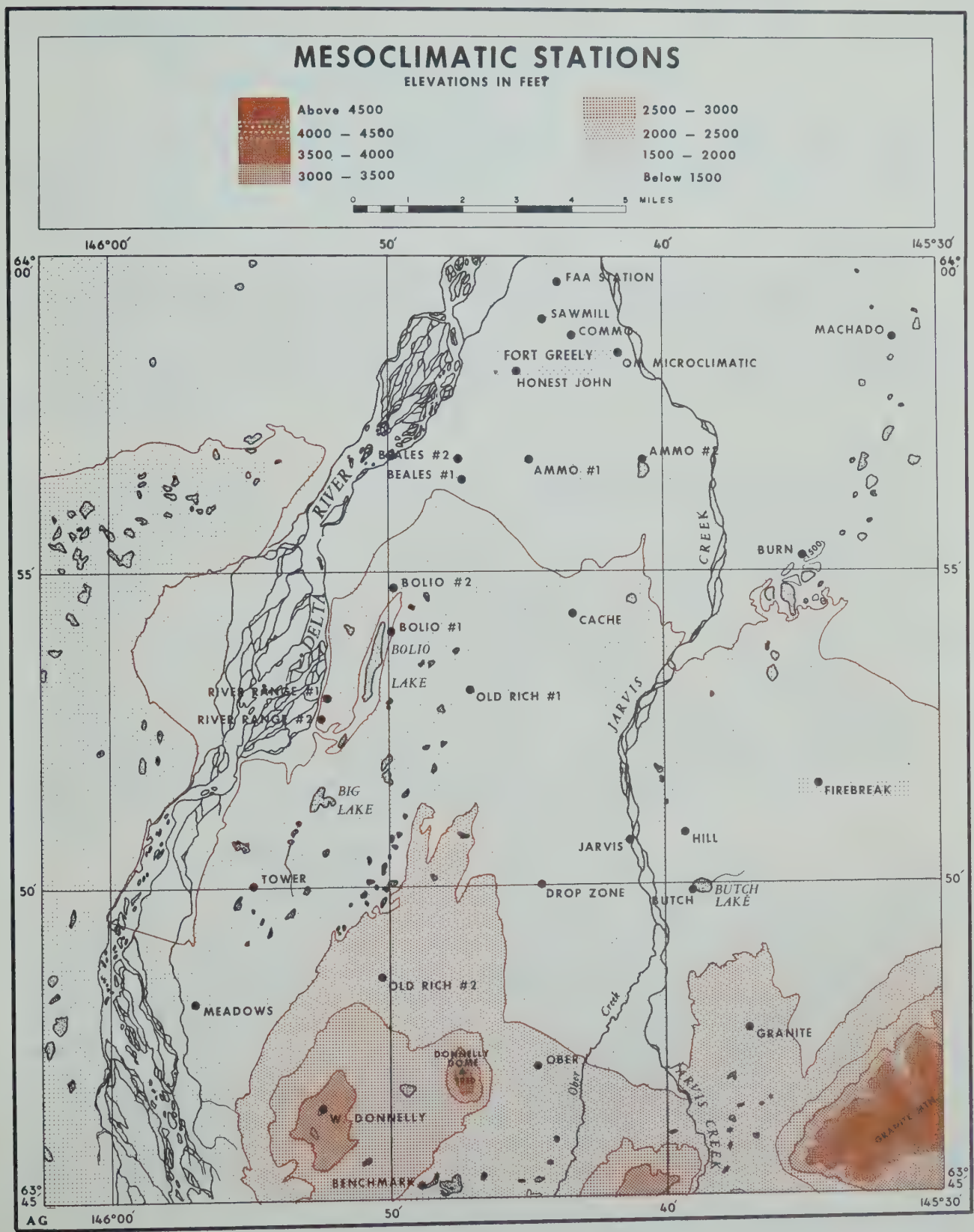

Figure 1

3. Mesoclimatic data

a. Daily temperature ranges at the FAA station

The daily ranges of temperature at the FAA station for the period from July 1955 through June 1957 are shown in Figure 2. These data demonstrate the most important characteristic of the temperature regime at Fort Greely: variability. During winter, cold or warm spells lasting more than 2 days are unusual.

When the location of Fort Greely is considered, these rapid changes are not surprising, for the area is subjected alternately to relatively warm maritime air masses and to very cold continental air masses - the latter sometimes from the Siberian cold pole. Some of the variability in Fort Greely weather can be attributed to local effects of the nearby mountains and to katabatic winds. These have been discussed by Evans[4,5], Ehrlich[8], and Mitchell[9].

However, some of the variations in temperature at Fort Greely are due not to local effects of the mountains or alternating air masses, but to the arctic surface inversion. In large areas of the Arctic and Subarctic, cooling at the earth's surface causes the creation of an air mass characterized by temperatures at the surface as much as 40 F° lower than temperatures from a few hundred to several thousand feet aloft[7]. Radiation exchanges between these air strata of different temperatures can cause rapid variation in the temperature of either stratum, and mixing by wind will cause modification of the entire air mass. The surface inversion is very common in northern areas. A clear area and a nearby cloudy area may have temperature differences of as much as 30 F° during cold periods when the inversion is strongly developed. According to Evans, "the relationship of wind, cloud cover, and radiation to free air temperature during the arctic winter is such a delicate one that obscure meteorological phenomena assume an exaggerated importance in temperature determination"[5].

b. Monthly maximum and minimum temperatures, 24 sites

Tables I and II show maximum and minimum temperatures respectively for a 25-month period at the thermograph stations. When it was determined by crosschecking of data that monthly extremes might be missing, no value is given; thus the tables serve as a rough indication of the completeness of record. In some months the extremes occurred on different days of the month at different stations. Other months had well-defined periods of extremes. For example, in June 1957 nearly all maxima occurred on the 10th, while all minima occurred on the 24th. The highest and lowest maxima and minima during each month are underlined in the tables and the ranges between these two values are given in the bottom row of each table. The differences between the indicated maxima and minima are not the largest differences which occur between sites, since the temperatures are often not simultaneous values.

DAILY RANGE IN TEMPERATURE AT BIG DELTA, ALASKA DURING A TWO-YEAR PERIOD

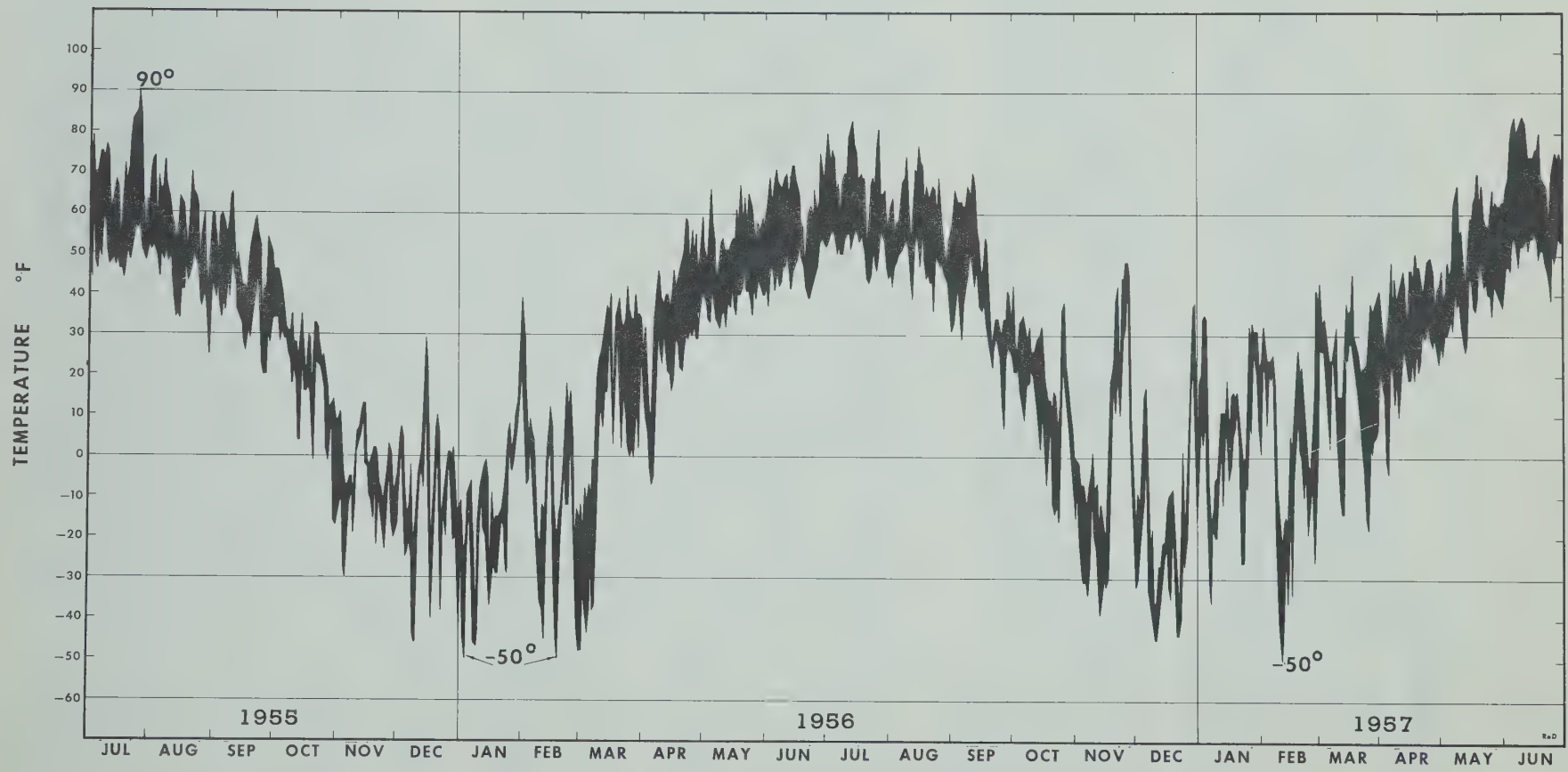

Figure 2

Table I

MAXIMUM MONTHLY TEMPERATURES (°F) AT 24 SITES, FORT GREELY, ALASKA

Period of record: June 1955 - June 1957

Station	Elev. (feet)	1955 Jun	Jul	Aug	Sep	Oct	Nov	Dec	1956 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1957 Jan	Feb	Mar	Apr	May	Jun
Benchmark	2,500	64	84	64	60	47	26	23	26	30			58	72	75	71	66	39		34	37		40	45	68	79
Old Rich #2	2,425	62	81	68	62	47		27					63	70	79	71	66	38	42	35	40		40	46	69	81
Ober	2,300							29	30	32		61	60	71	79	73	67	39	43	34	40	36	41	48	69	84
Granite	2,250	71	87	67	65	50	14	27					65	69	82	75	68	39	45	35	40	41	43	49		82
Hill	1,950					46	07	29	25		41		63	73	77	78		42		34	34	41	43	47	71	85
Butch	1,850	75	92	69	68	49	09	25	05	10			63	82	90	90	70	42	44	33	40	31	43	44	66	82
Drop Zone	1,750	72	88	73	67	49			23	19			66	73	81	73	70	40	42	31			42	51	75	85
Old Rich #1	1,700	70	87	71	65	48	10	25	10	26	35	55	69	75	78	74	71	42	49		39		43	49	70	84
Firebreak	1,625	78		74	67	48		35				63	69		84	79	80	44	54	43	39	47	54	54	82	88
Tower	1,625	70	92	75	64	51	10	25	33	34	40		61	73	81	72	71	41		36	36	36	46	48	68	80
Bolio #2	1,600	71				43	16	16	17	33			68	75	82	76	71	41	48	46	44	46	50	51	70	85
River Range	1,600	71	88	72	65	50	12	26	26	35		60	65	73	77				46			38			71	82
Cache	1,575						11	27			39	58			80	80	69	38	47		30	40	51	54	69	80
Meadow Range	1,550	81	90	72	62	47	29	28	34	40	42	56	65	75	82	74	70	40	47	37	36					
Bolio #1	1,500	73	89	72	66	49	14	25					65		82	75				36	32	38	44	51	70	81
Burn	1,500	73	87	70	62	40	09	24				58	59	71	82	69	66	37	44	34	32	36	45	50	67	84
Beales #1	1,470	75	89	73	67	47	15	37	22	43	41	61	65	76	83	77	69	37	48	37	35	41	43	51	68	84
Ammo #1	1,450	77	91	74	65			23	11	36	40	64	72	77		77	71	41	46	30	34	41	45	50	74	86
Ammo #2	1,450	77	91	74		45	11	22	22	36	42	57	62			75	70	38	45	37	36	40	46	47	67	88
Beales #2	1,450	77	88	71	65	46	11		39	34	39	59	64	71	80	73	68	41	46	36	38	46	43	49	73	86
Machado	1,275	75	89	74	67	47	14	27	16	40	41	60	66	77	84	77	70	42	45	25	34	38	43	47	70	81
FAA STATION	1,268	76	90	74	65	46	13	29	14	39	42	59	67	75	83	77	70	42	48	38	35	41	43	50	70	85
Sawmill	1,225	71	83	65	61	38	14	26	15	38	41		67	75	84	75	69	41	48	26	31	36	47	51	71	87
Confluence	1,200						11	27	08	39			65	75	83	77	66	41	47	32	36	40	44	49	70	85
Range during month		19	11	11	08	13	22	21	34	33	07	09	14	13	15	21	14	07	12	21	13	16	14	10	16	09

The highest and lowest values for each month are underlined

Table II

MINIMUM MONTHLY TEMPERATURES (°F) AT 24 SITES, FORT GREELY, ALASKA

Period of record: June 1955 - June 1957

Station	Elev. (feet)	1955 Jun	Jul	Aug	Sep	Oct	Nov	Dec	1956 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1957 Jan	Feb	Mar	Apr	May	Jun
Benchmark	2,500	33	39	27	18	-08	-19	-35	-43	-33				34	40	36				-29	-24	-32	-08	5	17	36
Old Rich #2	2,425	30	40		13	-02							31	35	39	33	06	-09		-32			-10	0	16	31
Ober	2,300										-35			34	40	30	05	-10		-34	-25		-10	05	18	39
Granite	2,250	31	40	22	14		-18	-31				-10	32		39	36	02	-14	-25	-32	-24	-34	-09	-19	22	36
Hill	1,950						-25	-33		-34	-34	-07	31	33	40	39		-14	-28	-35	-26	-24	-01	06	21	36
Butch	1,850	24	31	15	03		-31	-50				-16	26	26	31	25	-02	-26	-42	-56	-39	-61	-30	-08	15	32
Drop Zone	1,750	28	33	17	-01	-20		-54			-60		25	28	34	27	-08	-24	-38	-50			-34	-27	11	22
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Firebreak	1,625	18		12			-34	-54				-15	23	22	28	20	-19	-33	-44	-54	-53	-59	-25	-23	04	25
Tower	1,625	33	35	18	11	-13	-39	-39	-50				30		39	30	01		-35	-42		-50	-14	-04	15	32
Bolio #2	1,600	30				-20	-34							25	35	26			-37	-43	-46	-41	-26	-09	14	26
River Range	1,600	36	42	26	16	-15							31	35	43			-17				-41			22	37
Cache	1,575						-32				-39	-10				35	-03						-11	-02	20	36
Meadow Range	1,550	32	31	20	10	-16	-35	-50	-54	-54	-58	-19	25	29	37	27	-05	-26	-39		-43	-54				31
Bolio #1	1,500	26	35	19	12	-21	-36						24		41					-55	-48	-53		-18	18	23
Burn	1,500	31	34	19	08			-43				-09	27	27	35	31	0	-14		-40	-36		-13	-01	20	39
Beales #1	1,470	28	40	15	05	-19	-32		-53	-53	-53	-14	26	29	38	35	-01	-20	-36		-34			-01	26	42
Ammo #1	1,450	30	34	30	10			-55	-53	-55	-58			31	38	30	-02	-21	-38		-26	-52	-18	0	17	35
Ammo #2	1,450	29	34	21		-18	-31		-53	-53	-55	-12	20	34	36	30	-02	-18	-34	-45	-34	-52	-19	-04	22	32
Beales #2	1,450	27	32	21	11	-19	-36						27	29	37	20	-02	-24	-39	-47	-41	-42	-16	-07	17	30
Machado	1,275	26	31	16	10		-25						28		33	30	-05	-22	-36	-45	-39	-46	-16	-04	17	31
FAA STATION	1,268	35	44	25	20	-16	-30	-46	-50	-45	-48	-07	32	37	43	36	07	-16	-39	-45	-36	-50	-18	-04	25	39
Sawmill	1,225	19	27	15	04	-30	-45						28	29	39	31	01	-25	-40		-40	-55	-23	-11	19	30
Confluence	1,300						-40	-56		-58	-59		22	30	33	29	0	-24	-45	-57	-43	-57	-23	-13	20	36
Range during month		18	17	15	21	28	27	25	14	25	25	12	12	15	15	16	26	24	20	27	29	29	33	33	22	20

The highest and lowest values for each month are underlined

Many interesting relationships can be ascertained from inspecting together the tables of maximum and minimum temperature. For example, during several months Firebreak recorded both the highest and the lowest temperatures of all the sites and had monthly ranges of nearly 100 F° (during September 1956 the maximum was 80°F and the minimum -19°F).

4. Analysis of a February cold-weather and warm-weather period and a June clear spell and cloudy spell

Two 7-day periods in winter and two 7-day periods in summer were chosen to illustrate local temperature differences and variability in more detail. Temperature data for the FAA station and 2 thermograph sites for the following periods are charted and discussed:

In February	(a cold spell (1957) (a warm spell (1956)
In June	(a clear spell (1957) (a cloudy spell (1956)

a. The February temperature regimes

The temperatures for a 7-day period in February 1957 and for another 7-day period around early February 1956 are examined, for 3 weather observation sites. In the first period considered, the temperatures are below -20°F much of the time. In the second period discussed, the temperatures are above 20°F much of the time.

The cold weather of February 1957 (Fig. 3) During the first week of February 1957, a large high-pressure area centered south of the Aleutians caused a southerly flow with above-average temperatures in most of Alaska. On 8 February, a low moved into the Gulf of Alaska and interrupted this southerly flow, introducing cold air from the Siberian High. At Big Delta FAA, the lowest temperatures occurred on 10 and 11 February under nearly calm and clear conditions. The striking difference of more than 35F° between the temperature at a hilltop (Hill) and at a nearby low spot (Butch), less than one mile distant, is evidence that the cold air was very shallow.

The warm weather around early February 1956 (Fig. 4) During this period persistent low pressure in the Gulf of Alaska and high pressure in western Canada caused a channeling of relatively warm, moist air down the Tanana River Valley. On 2 February the pressure field allowed a strong southerly flow to cross the Alaska Range and replace the east-southeast surface flow which had been in control at the FAA station for about a week. By 4 February the Siberian High had built eastward and southward, bringing a period of cooler, but not unseasonably cold temperatures, to the area.

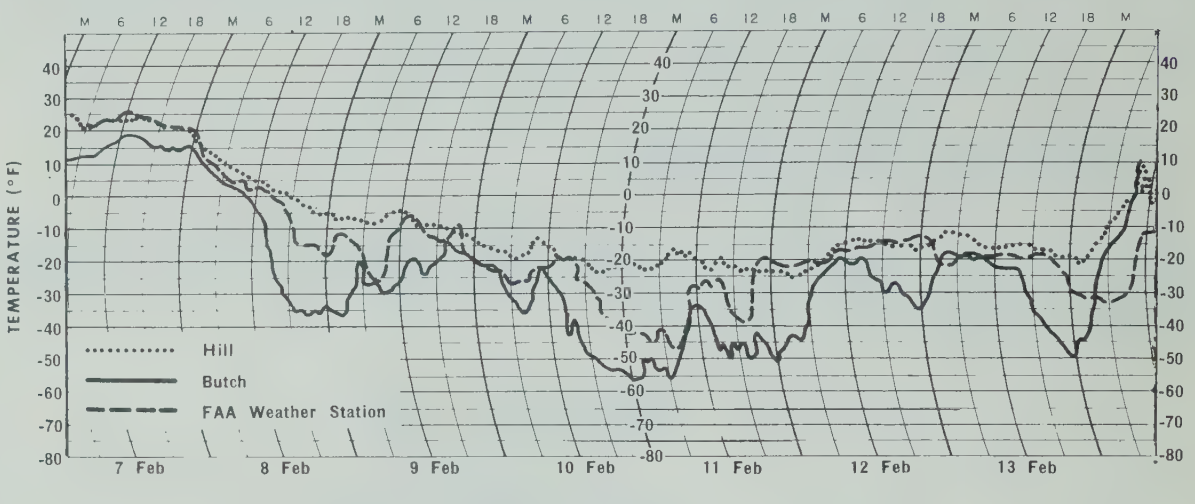

Figure 3

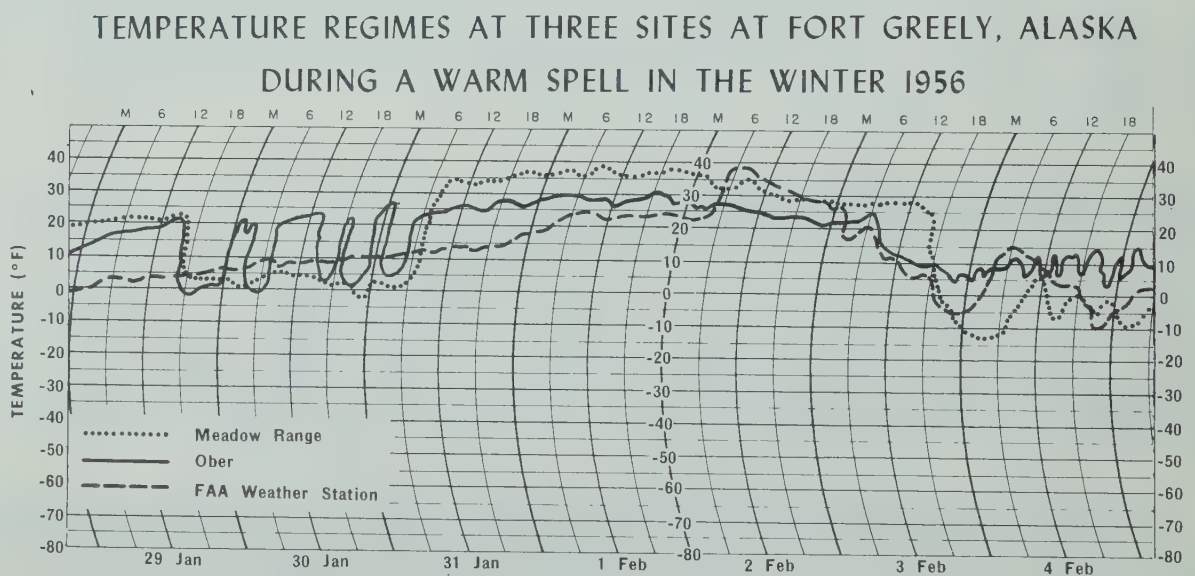

Figure 4

During this period a significant aspect of the temperature field at Fort Greely is evident. On 30 and 31 January temperatures at the Ober station fluctuated rapidly between the 20's and temperatures near 0°F. The southerly flow which reached the FAA station on 2 February apparently was intermittently in control at Ober. At Meadow Range this flow was interrupted from 1800, 29 January, to 0600, 31 January, when temperatures rose rapidly from 0°F to 35°F. There were no wind observations to confirm the presence of the southerly flow, but the temperature trace is evidence enough. Fort Greely is often the meeting ground of easterly and warmer southerly flows of air down the Tanana and Delta River valleys respectively, complicating the job of forecasters and military test planners.

b. The June temperature regimes

Temperatures during a 7-day clear spell in June 1957 and during a 7-day cloudy spell in June 1956 are examined for 3 sites to illustrate the differences in temperature regimes in summer under differing radiation conditions.

The clear weather of June 1957 (Fig. 5) The unusually pleasant weather of early June 1957 can be ascribed to subsidence aloft associated with a persistent high which is partially masked at the surface by the heating associated with long hours of sunshine. Lows passed well to the south of the Fort Greely area during the period, transporting mild Pacific air into the mainland. This air was modified by its passage over the Alaska Range, and, in combination with the high aloft, caused clear skies and a large diurnal range at Fort Greely.

Although at this time of year nights are short, ideal radiational cooling conditions prevail for a few hours each day and outgoing radiation exceeds incoming radiation almost half the time. The big differences from site to site in summer minima evident in Figure 5, are of particular concern to agricultural interests.

The unsettled weather of June 1956 (Fig. 6) In contrast to synoptic conditions during June 1957, relatively low pressure prevailed over the Alaskan mainland during mid-June 1956, with cloudy and intermittently rainy conditions. The temperature trends during this period illustrate the small differences which sometimes exist from site to site. Some of the differences between the temperature regimes at the various stations can be attributed to local variations in radiation: the rise in temperature at the FAA station on 19 June occurred during a sunny period at that site. Ober station and Meadow Range station apparently were cloudy at this time, and temperatures at these sites did not rise.

TEMPERATURE REGIMES AT THREE SITES AT FORT GREELY, ALASKA
DURING A CLEAR SPELL IN JUNE 1957

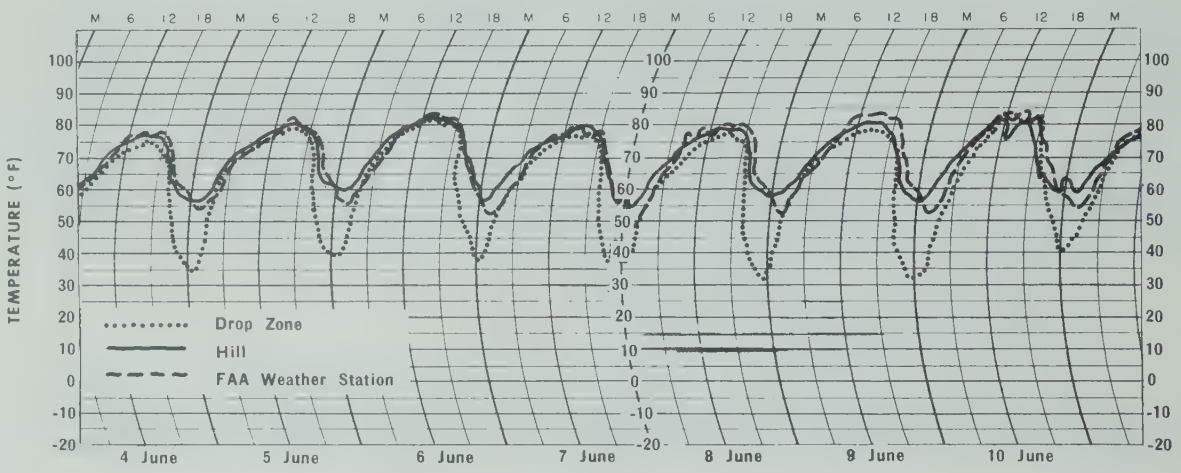

Figure 5

TEMPERATURE REGIMES AT THREE SITES AT FORT GREELY, ALASKA
DURING A CLOUDY SPELL IN JUNE 1956

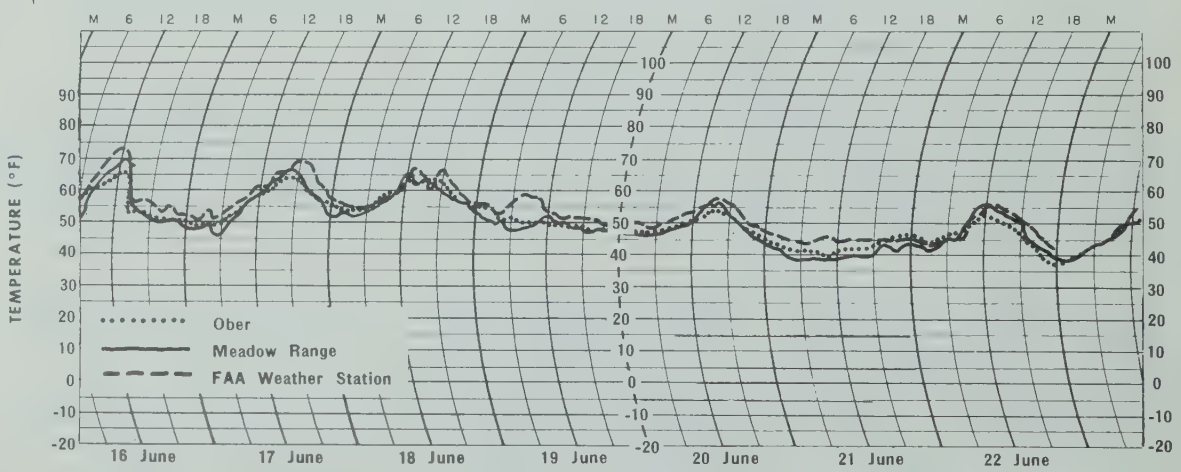

Figure 6

5. Location and extent of departures of minimum temperatures from FAA station temperatures

Figure 7, 8, and 9 show differences in low temperatures from FAA station during extremely cold periods, moderately cold periods, and on clear summer nights in the Fort Greely, Alaska, area.

a. During extremely cold periods (Fig. 7)

Figure 7 was prepared after considering the temperature at all thermograph sites during 10 cold spells during the winters of 1955, 1956, and 1957, when the FAA station had a minimum temperature below -40°F, skies were clear, and winds light. The thermograph clocks were not considered to be accurate enough in very cold weather to permit comparison of simultaneous values at all sites, so minimum temperatures (not necessarily simultaneous) were compared. Temperatures at each station for the 10 cold spells were tabulated and mean and median values determined. In no case did the mean vary from the median by more than 2 F°. Actual patterns of cold varied considerably from cold spell to cold spell, so the map can be considered as representative of only average conditions. It does not show an actual recorded distribution of temperatures.

Figure 7 shows that the Delta River lowland, Bolio Lake, and Butch Lake areas normally have minimum temperatures in very cold periods 10 to 15 F° lower than the minimum at the FAA station. Much of the lower land south and east of the Big Delta airport normally has minima slightly lower than those of the FAA station, while the higher land to the south remains considerably warmer. The lowest temperature at the FAA station during the study period was -50°F. Some higher sites to the south did not record temperatures below -35°F during the 3 years of record. Average differences in temperatures between the cold and warm areas of more than 25F° are evident from the map.

b. During normally cold periods (Fig. 8)

This map shows normal variations in the temperature field under conditions of clear skies, light winds, and FAA station temperature between -11°F and -20°F. The difference in temperature between FAA and a given field station was equal to or less than the indicated value on 50 percent of the occasions. Evans' map differs from the preceding map in that it shows median differences rather than mean differences, based on simultaneous values at all sites. Evans' sample, based on hourly data rather than daily minima, is larger. Evans selected the temperature range of -11 to -20°F because he felt that the most difficult forecasting problems occurred when the FAA temperature was in this range. He felt that at lower temperatures the differences from site to site were not as great and were

FORT GREELY AREA - ALASKA

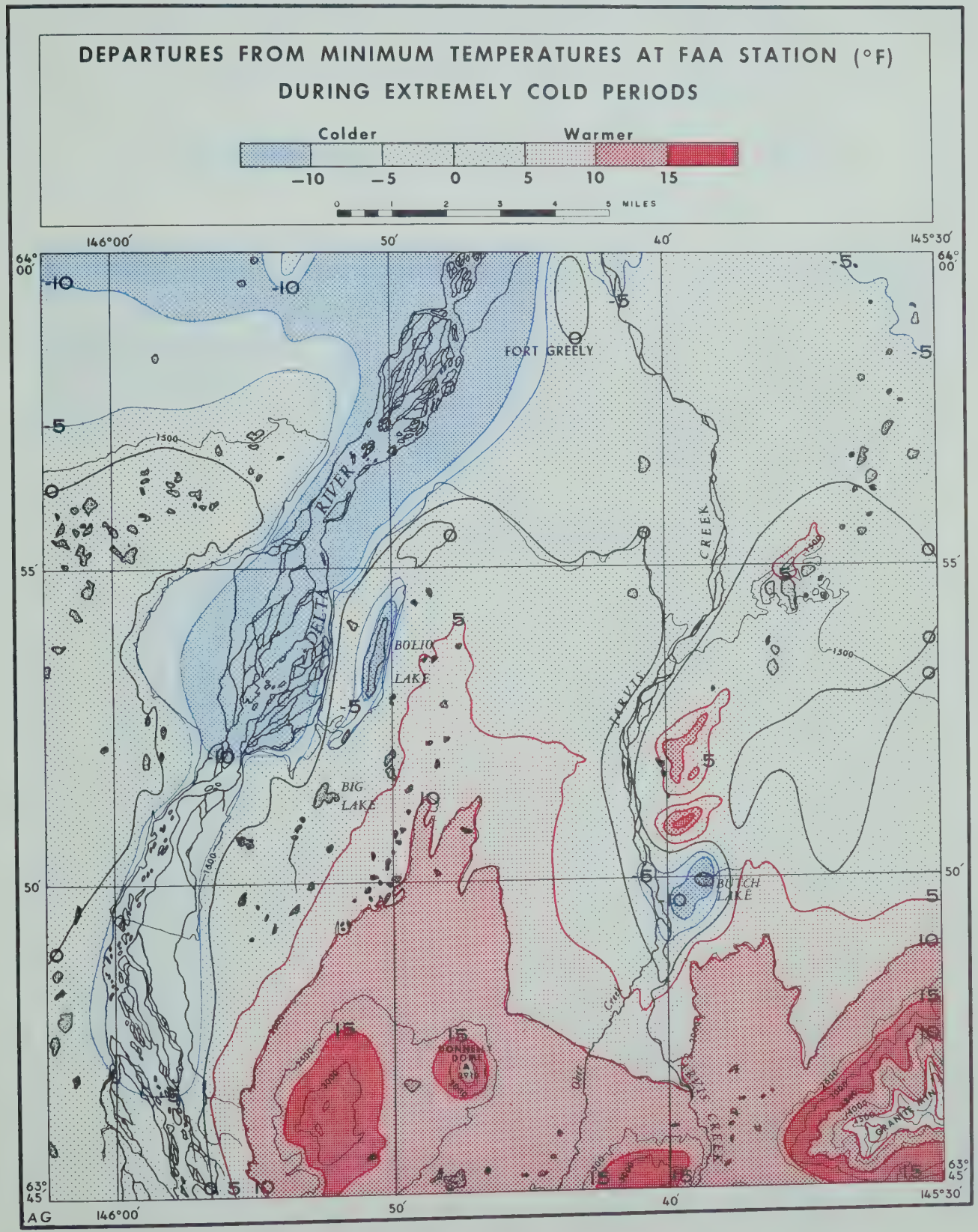

Figure 7

FORT GREELY AREA - ALASKA

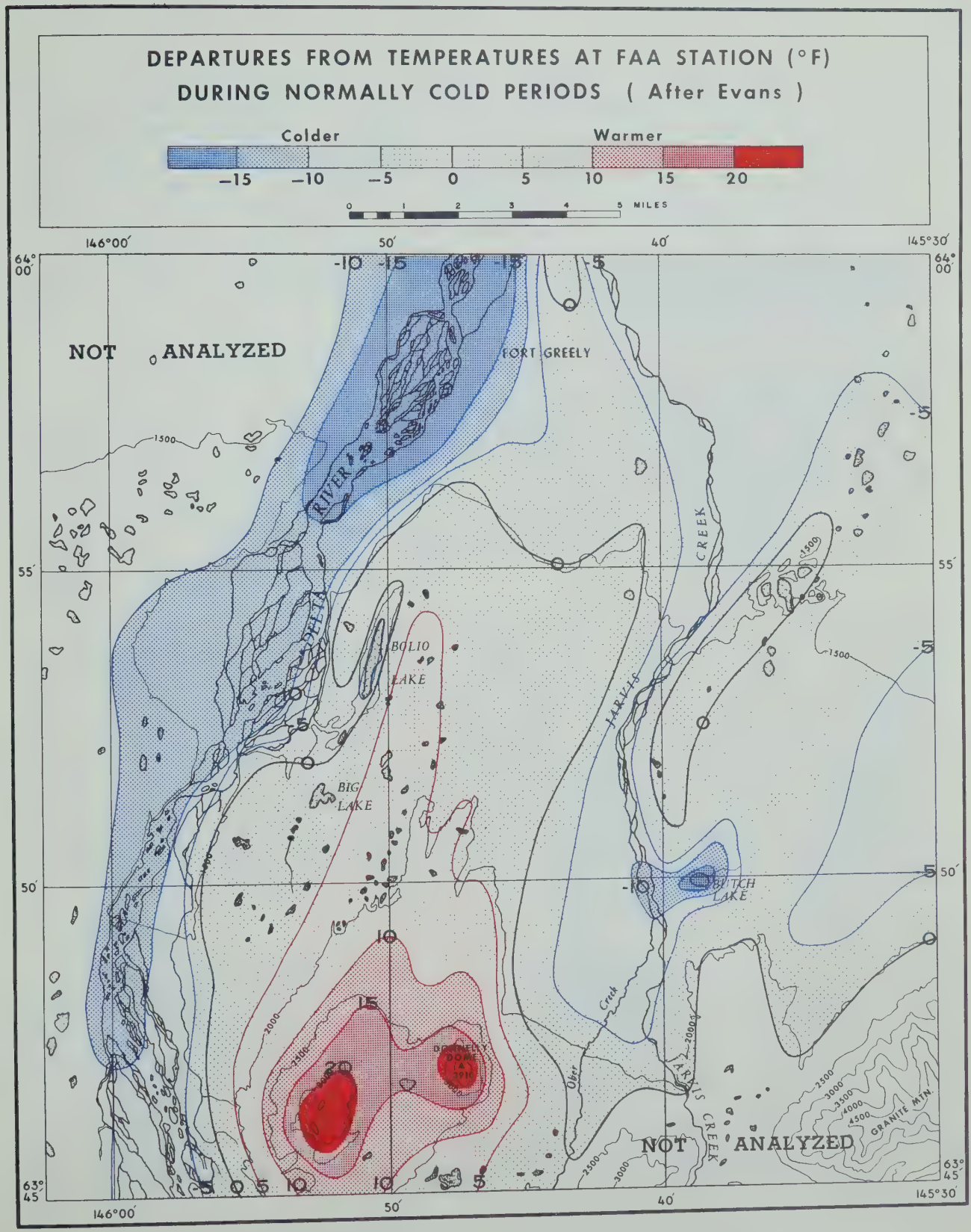

Figure 8

easier to forecast. Comparison of this map with the map of differences during extreme cold (Fig. 7) bears out this assumption to some extent, for the differences are not as large on Figure 7. The two maps showing temperature differences during extremely cold and normally cold conditions can be compared only in a general way since they were prepared from different samples of data. In view of these differences, the patterns of differences from the FAA temperatures are similiar enough to confirm the nature of departures of temperatures during cold periods in the Fort Greely area from those at the FAA station. Average differences in temperatures between cold and warm areas of more than 35F° are evident from the map.

c. During clear summer nights (Fig. 9)

This map shows typical variations in the temperature field under conditions of clear skies and light winds during summer nights. It was prepared in the same manner as Figure 7. This summer pattern of temperature variation from the minimum at the FAA station differs from the pattern during winter (Figs. 7 and 8) in that the higher stations in the south had average minima about the same as the average minima at the FAA station. Figures 7 and 8 showed that in winter these stations had minima that averaged as much as 20 F° higher.

The winter cold spots (Figure 7 and 8)--Butch Lake, Bolio Lake, and the lowlands along the Delta River--also had low summer minima (Fig. 9). To the east, however, Machado and Firebreak had distinctly lower minima than FAA, indicating more difference in summer than in winter. The lower minima at these stations in summer cannot be explained, but they may be associated with differences in vegetation cover between summer and winter. Low minimum temperatures at Firebreak are particularly interesting because this station also had high maximum temperatures, resulting in extraordinarily large temperature ranges on some days. On several occasions Firebreak experienced daily ranges of greater than 60 F°. On 25 May 1957, the maximum at Firebreak was 78°F and the minimum was 15°F.

6. Summary

Fort Greely, Alaska, located near mountain passes in an area which is subjected alternately to relatively warm maritime air masses and very cold continental air masses during the colder half of the year, is characterized by a large variation in temperature from day to day. In winter either warm or cold spells lasting more than 2 days are unusual. There is also large variation in temperature from place to place because of the influence of the mountains and terrain that causes cold air drainage. During cold spells some sites are as much as 20 F° warmer than the FAA station while other sites are 15 F° colder. These differences must be considered in test planning.

FORT GREELY AREA - ALASKA

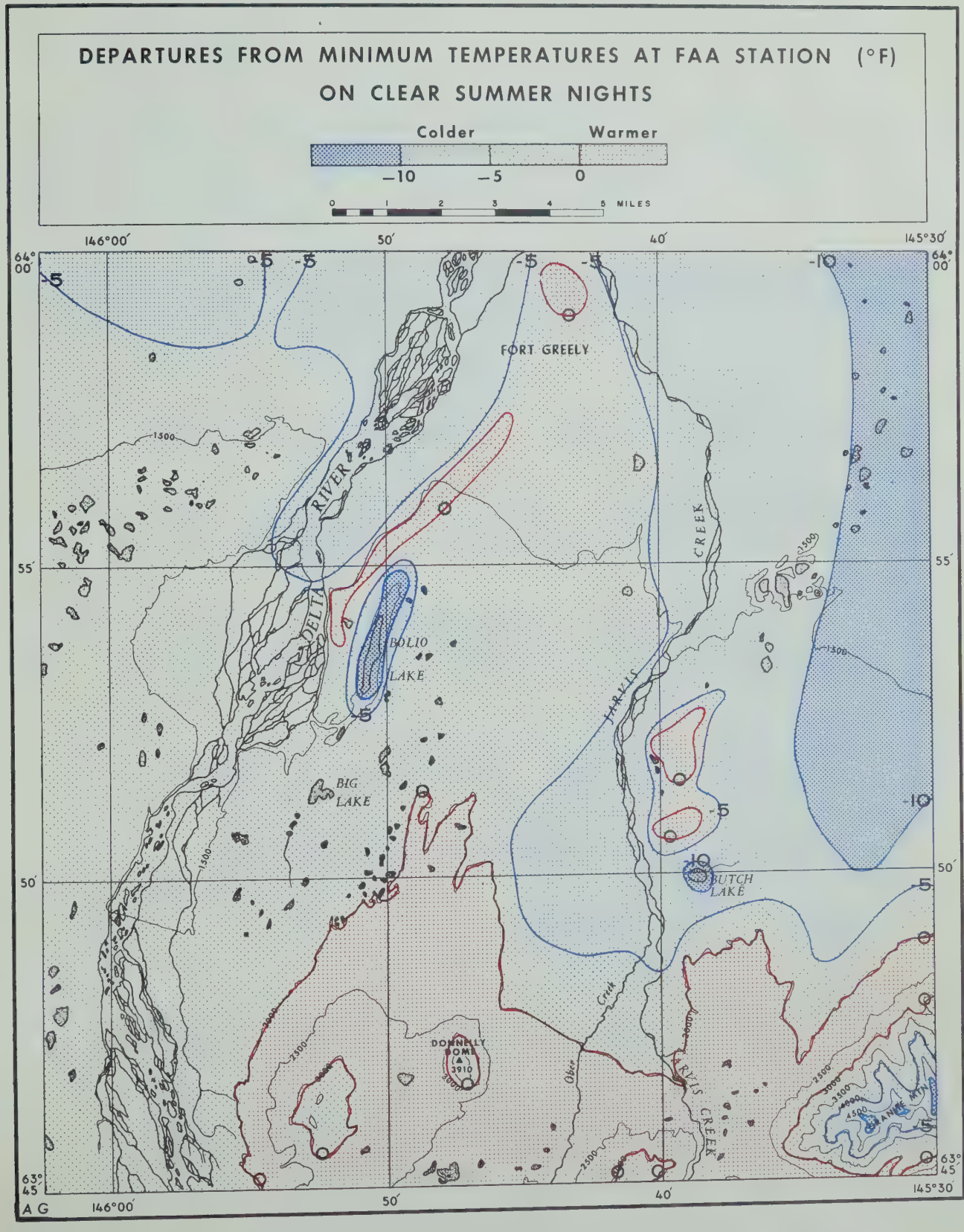

Figure 9

7. Acknowledgments

Many people were involved in the planning and observational program at Fort Greely, Alaska. Credit for accomplishing the difficult observational program is due the officers and men of the Signal Corps and Air Force meteorological groups at Fort Greely. Data were transcribed from thermograph charts to tabular form at the National Weather Records Center, Asheville, North Carolina.

Mr. Donald Hogue, Earth Sciences Division, assisted in preparing the data for analysis. Cartography was accomplished by Roland Frodigh, Aubrey Greenwald, and Russell Dearborn, all of this Center.

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A P P E N D I X

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Figure 10 Instrument shelter and rain gage at Federal Aviation Agency station with Big Delta airport in background. Elevation 1,268 feet.

Figure 11 Benchmark thermograph station near Richardson highway 2 miles south of Donnelly Dome. Scattered white spruce are found in area near timberline. Elevation 2,500 feet.

Figure 12 Firebreak thermograph station in wooded area northeast of Butch Lake. This station experienced daily ranges in temperature up to 60 F°. Elevation 1,625 feet.

Figure 13 Drop Zone thermograph station in low shrub setting next to Richardson highway. Elevation 1,750 feet.

Figure 14 Old Rich # 2 thermograph station on gently sloping open land 2½ miles northwest of Donnelly Dome. Elevation 2,425 feet.

Figure 15 Machado thermograph station near the Alaska Highway in young mixed evergreen-deciduous forest. Elevation 1,275 feet.

Figure 16 Burn thermograph station near tank trail in area of aspens burned in 1955. Elevation 1,500 feet.

Figure 17 Bolio Lake is the primary site of current cold-weather testing.

Figure 18 Bolio # 1 thermograph station on lake shore near road shown in Figure 17. Elevation 1,500 feet.

Figure 19 Sawmill thermograph station at base of Big Delta bluff. This station experiences cold air drainage. Elevation 1,225 feet.

Figure 20 Granite thermograph station in shrub tundra with Granite Mountains in background. Elevation 2,250 feet.

Figure 21 Butch thermograph station in depression near Butch Lake often is the coldest spot in Fort Greely Test Area. Elevation 1,850 feet.

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